Seismic wave phase velocity variations in the state of Ohio

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Introduction

Since 1776 more than 160 felt earthquakes have occurred in the state of Ohio. In 1999 the Ohio Seismic Network started recording the most recent events. The waves of these earthquakes have various phases with different velocities. These velocities are suspected to fluctuate as they travel through Ohio.

The first arrival waves are P waves, which are divided into the direct P wave, Pg, and the from the hypocenter downwards travelling Pn wave. The S waves are called Sg, and Sn.

The downward-traveling waves intersect the Moho, increase in velocity and come back to the surface at a distance of about 200 km or more (crossover distance). In case of an earthquake occurring at a distance greater than 200 km from the seismic station, Pn is recorded as the first-arrival wave, followed by Pg, Sn and Sg.

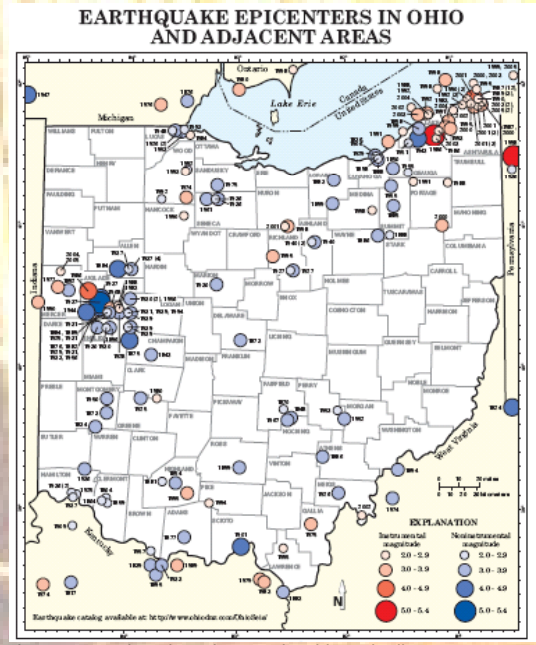

Figure 1. Earthquake epicenters in Ohio and adjacent areas map from Ohio Geological Survey online http://www.dnr.state.oh.us/geosurvey/html/earthmap/tabid/8291/Default.aspx

Significance

The accuracy of velocity changes is important to determine precise locations for local and regional earthquakes. Therefore the average travel time of each wave phase of several earthquakes is calculated to obtain the most accurate velocity model for a region or area. For this the events have to be recorded by many seismic stations at varying epicentral distances. Differences of velocities may be due to variations in crustal geology to which the models have to be adjusted. Currently, the Ohio Seismic Network uses a velocity model created by Dr. Larry J. Ruff at the University of Michigan on data gathered by the Anna Seismic Network between 1977 and 1992. Since then the Ohio Seismic Network has been recording events which will contribute to a new model.

Method

The Ohio Seismic Network velocity model uses the following velocities for wave phases in Ohio:
Pg – 6.12 km/sec, Pn – 8.05 km/sec,
Sg – 3.5-3.8 km/sec, Sn – 4.5 km/sec.
To determine the true velocities, the actual and the expected arrival times of each wave phase are calculated for a number of earthquakes at varying epicentral distances and azimuths.

Location	Date	Magnitude	avg. Pn velocity	avg. Pg velocity	avg Sn velocity	avg Sg velocity
Ashtabula, OH	1/26/2001	4.5	7.2154415	6.071994	3.910873	3.560341
Illinois	4/18/2008	5.2	7.456427	6.150453	4.511398	3.651916
Evansville, IN	6/18/2001	5	7.03127	6.0839	4.229897	3.55254
Arkansas	2/10/2005	4.1	7.913381	6.181748	4.499604	3.619213
Plattsburgh, NY	2/4/2002	5.1	7.837456	6.347313	4.363382	3.690418
Quebec	3/6/2005	4.9	8.033508	5.749264	4.498661	3.670868

Figure 1. Observed wave phase velocities of various events with increasing distance

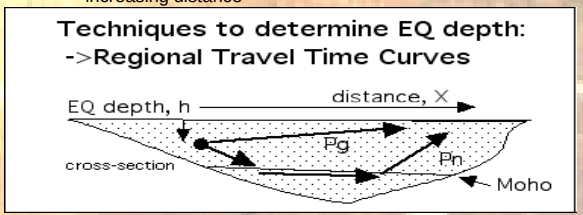

Figure 2. Travelpaths of Pg and Pn, relationship to distance

Future Research

Time arrival differences between two stations allow us to determine crustal geology which may interfere with wave velocities of the various phases.
This would help in developing new velocity models for the state of Ohio.

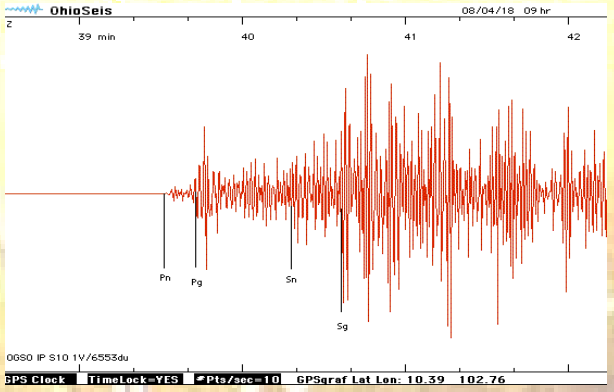

Figure 3. Seismogram of the 04/18/2008 Illinois earthquake recorded by the station OGSO; various wave phases are indicated.

Conclusions

After examining several well-recorded local and regional events, discrepancies of most actual arrival times from the expected arrival times can be observed.
Preliminary trends indicate increasing velocities of the Pn and and Sg waves with increasing distance, while Pg and Sn fluctuate without obvious trends.
A probable explanation for these variations is that the crustal structure below Ohio influences inconsistencies in phase velocities. Additional research may provide sufficient information to determine if these variations are related to specific basement structures as well as help to create local velocity models to be used in earthquake location programs.

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